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Mission Highlights STS-73

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Second flight of USML furthers science in space

Early morning clouds at the Kennedy Space Center cleared on Friday, October 20, 1995, sending Space Shuttle *Columbia* off on the second longest shuttle flight to date. The 8:53 a.m. CST launch of STS-73 marked the beginning of a 16-day mission to explore the resource of weightlessness in the United States Microgravity Laboratory-2 (USML-2).

Columbia and a crew of seven astronauts sailed smoothly through a slate of investigations involving weightlessness and encompassing an array of studies ranging from fluid physics to materials science to biotechnology and combustion. The USML-2 Spacelab mission continued a cooperative effort of the U.S. government, universities and industry to push back the frontiers of science and technology in "microgravity," the near-weightless environment of space.

Combining the strengths of these different communities allowed for more extensive ground-based research in preparation for flight, improved methods for microgravity experimentation, and a wider distribution of the knowledge gained in the process. The involvement of U.S. industry also meant that the results of both ground-based experiments and shuttle operations could be 'brought down to Earth' in a timely and practical manner.

Also during the STS-73 mission, students at four sites interacted with *Columbia's* astronauts to discuss and compare onboard microgravity experiments with similar ground-based experiments. The goal was to involve students as participants in shuttle investigations in an effort to generate

Mission Specialist Kathryn Thornton and Commander Ken Bowersox monitor the experiments on the Drop Physics Module.

Space Shuttle *Columbia*

October 20-November 5, 1995

Commander:	Ken Bowersox
Pilot:	Kent Rominger
Mission Specialists:	Catherine Coleman Michael Lopez-Alegria Kathryn Thornton
Payload Specialists:	Fred Leslie Albert Sacco

Mission Specialist Cady Coleman conducts experiments on USML with the help of the Glovebox.

excitement in physical science and chemistry.

UNITED STATES MICRO-GRAVITY LABORATORY-2 (USML-2): Fluid physics research with the Drop Physics Module, the Surface Tension Driven Convection Experiment and the Gravitational Fluid Flow Cell sought to improve understanding of fluid behavior and to apply that understanding to processes of scientific and technical importance. Without the pull of gravity and the associated convective flows, more perfect crystals can be produced, an advance many believe vital for creation of advanced computer chips and semiconductors.

Biotechnology research on USML-2 grew protein crystals in three different experiment facilities and attempted to produce crystals of sufficient size and perfection that scientists can determine their structure and how they form. This approach was pursued because of the promise it holds for the development of improved drugs. Two other biotechnology experiments addressed the development of food crops with higher protein content and increased disease resistance.

Combustion science, a study of how the basic combustion process is affected by gravity, was represented by one of seven technology investigations within the versatile Glovebox enclosure. Understanding the way a fire starts and spreads without the interference of gravity could lead to more efficient fuels and improved fire safety, both in space and on Earth.

Commercial space processing technologies were demonstrated with the Commercial Generic Bioprocessing Apparatus, giving a large number of university and industry researchers access to space for their biological experiments. Techniques for plant cultivation in microgravity were further advanced in the Astroculture facility.

Several investigators were able to view live video of their experiments at the same time, thanks to the new six-channel Hi-Pac video downlink system which made its first flight on USML-2.

PAYLOAD DESCRIPTIONS

Surface Tension Driven Convection Experiment: The Surface Tension Driven Convection Experiment apparatus allowed investigators to view in great detail the basic fluid mechanics and heat transfer of thermocapillary flows, motions created within fluids by non-uniform heating of their free surfaces.

In space, under microgravity conditions, thermocapillary flows become prominent and can be studied in detail. Knowledge of their behavior and effects is important to a thorough understanding of fluid physics. It is also necessary because these flows affect space applications such as bubble and droplet migration, fuel management and storage, and life support systems, as well as material processing methods like crystal growth from liquids, containerless processing, and welding. The principal investigator was Case Western Reserve University, Cleveland, OH.

Other aspects of fluid physics were studied using the **Drop Physics Module** which acoustically positioned and manipulated free-floating liquid drops to test and expand current fluid physics models and theories and to measure the properties of liquid surfaces.

In space, where gravity's overwhelming influence is minimized, scientists can unmask and study more subtle forces that drive fluid behavior. This fundamental knowledge can be beneficial for a variety of industries on Earth, from pharmacology to industrial chemistry.

Drop Dynamics Experiment: This experiment gathered high quality data on the dynamics of liquid drops in low gravity for comparison with theoretical predictions and ground-based studies using very small drops. It provided scientific and technical inputs for the development of new fields, such as containerless processing of materials and polymer encapsulation of living cells.

The second thrust of this effort attempted to lay the ground work for encapsulating living cells which could be used to treat hormonal disorders: a spherical polymer shell would protect the cells from immunological attack and provide timed release.

In the case of diabetes, an improved treatment would be to inject a pancreatic cell that secretes insulin into the body, rather than injecting insulin itself. But the foreign cell would be immediately attacked by the patient's immune system. If the cell were encapsulated in a spherical shell made of a material strong enough to withstand attack, yet porous enough to allow absorption of nutrients and excretion of insulin, it could enable a marked improvement in treatment for diabetes patients. The principal investigator for the Drop Dynamics experiment was Vanderbilt University, Nashville, TN.

Science and Technology of Surface-Controlled Phenomena: This study used the Drop Physics Module to examine the influence of surfactants on the behavior of drops. Surfactants are substances that alter the surface properties of a liquid, aiding or inhibiting the way it adheres to or mixes with other substances. Processes which rely heavily on surfactants are as varied as dishwashing (soap and water is the classic surfactant-liquid interaction), the manufacture of cosmetics, the dissolution of proteins in synthetic drugs, the recovery of oil and environmental cleanup. The principal investigator for this experiment was Yale University, New Haven, CT.

Geophysical Fluid Flow Cell Experiment: The purpose of this experiment was to study how fluids move in a spherical symmetric system with radically-directed acceleration similar to Earth's atmosphere or a planet, helping researchers understand the large-scale fluid dynamics of planetary and stellar atmospheres.

The experiment could not be done in ground-based labs because the downward pull of Earth's gravity overwhelms the artificially created "gravity" that is directed toward the center of the sphere. In microgravity, different forms of acceleration can be simulated without interference. The principal investigator was the University of Colorado, Boulder.

Crystal Growth Furnace: The Crystal Growth Furnace was a reusable Spacelab facility for growing crystals of semiconducting material, metals and alloys.

Crystallization can be more effectively studied in microgravity than on Earth, because the gravity-induced phenomena that obscure or change the process are greatly reduced or eliminated. Gravity-related complications such as convection, sedimentation and buoyancy can result in problems ranging from physical flaws in the internal structure of the crystal to uneven distribution of component materials within it.

By analyzing space-grown crystals with well-defined, orderly atomic structures, investigators can increase their knowledge of many types of materials both in space and on the ground. In the future, this knowledge could result in improved materials, processing techniques, or products here on Earth.

Compound Semiconductors: This experiment examined the effects of gravity on the growth and quality of alloyed compound semiconductors. It attempted to produce high quality cadmium zinc telluride crystals with fewer physical defects and more uniform distribution of chemical components than those grown on Earth. The principal investigator was Northrop-Grumman Corp., Research and Development Center, Bethpage, NY.

The Study of Dopant Segregation Behavior During Crystal Growth of Gallium Arsenide (Gaas) in Microgravity: This experiment investigated techniques for uniformly distributing a small amount of selenium within a gallium arsenide crystal as it grows in microgravity. Electronic devices made from gallium arsenide crystals operate at higher speeds and use less power than computer chips and other semiconductor applications made from silicon. Gallium arsenide is used in high-speed digital circuits, optoelectronic integrated circuits, solid-state lasers, and a variety of other products. The principal investigator was Case Western Reserve University, Cleveland, OH.

Zeolite Crystal Growth Experiment: This experiment studied techniques for growing large zeolite crystals in microgravity. Zeolite crystals are used in the chemical process industry as filters, catalysts for reactions and absorbents. Their three-dimensional crystal structures are capable of selective filtration so zeolite crystals are often used as sieves to selectively filter molecular compounds. These crystals also have potential applications as nuclear waste scavengers and are useful as quantum confinement hosts for semiconductor materials. Theoretically, large zeolite crystals, 500 to 1000 times the size of crystals grown on Earth, can be grown in microgravity. The principal investigator was Worcester Polytechnic Institute, Worcester, MA.

Vapor Transport Crystal Growth of Mercury Cadmium Telluride in Microgravity: The purpose of this experiment was to understand the initial phase of the process of vapor crystal growth of complex alloy semiconductors by growing a crystalline layer of mercury cadmium telluride on a cadmium telluride substrate using the vapor transport method; to determine the effects of microgravity on the growth rate, chemical composition, structural characteristics, and other properties of the crystalline layer. These crystals have applications as infrared detectors in space, defense, medical, and commercial systems. Better understanding of this crystal growth method will enhance ground-based production of similar semiconductor materials and lead to further improvements in techniques for producing crystals using this process. The principal investigator for this experiment was the Rensselaer Polytechnic Institute, Troy NY.

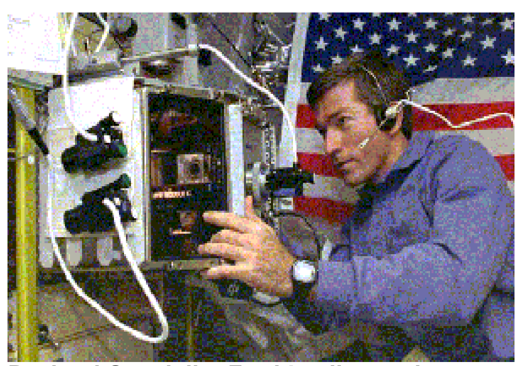
Glovebox Facility: The Spacelab Glovebox, provided by the European Space Agency, was a versatile, transparent enclosure where experimenters could test and develop procedures and technologies in microgravity. The principle investigator was NASA's Marshall Space Flight Center, Huntsville, AL.

Colloidal Disorder-Order Transitions: This Glovebox investigation looked at how the density of a substance finely and uniformly dispersed within another substance of a different phase, a mixture called a colloid, affects its transition from a liquid to an ordered solid phase.

A better understanding of what happens at the boundary between solid and liquid states of a colloid should help researchers improve materials processing methods on Earth, as well as in microgravity. The principal investigator was Princeton University, Princeton, NJ.

Particle Dispersion Experiment: This investigation used the microgravity environment to study how fine natural particles, such as dust, disperse within an atmosphere, then assemble back together (or reaggregate) into larger clusters.

In addition to helping scientists understand how planetary atmospheres are cleansed of dust injected by volcanic eruptions, meteorite impacts or dust storms, the experiment tested technologies for future shuttle and space station experiments concerned with the dispersion of aerosols. The principal investigator was NASA's Ames Research Center, Moffett Field,



Payload Specialist Fred Leslie monitors the Oscillatory Thermocapillary Flow Experiment.

Pilot Kent Rominger prepares equipment for air sampling.

CA.

Protein Crystal Growth Experiments: A record number of protein crystal growth experiment facilities aboard USML-2 were used to produce large, well-ordered crystals of various proteins under controlled conditions in microgravity. The crystals were then used in ground-based studies to determine the molecular structure of each protein.

Proteins play important roles in daily life, from providing nourishment to fighting disease. The benefits of these experiments include new information on basic biological processes, development of food crops with higher protein content and increased resistance to disease, and basic research toward the development of more effective drugs.

For many crystals, those grown in microgravity show a more uniform and highly ordered structure with fewer defects than are found in crystals of the same proteins produced on Earth.

Single-Locker Protein Crystal Growth - Two Methods: This experiment processed more than 800 protein samples in a facility designed for the production of crystals with enhanced internal order. The Protein Crystallization Apparatus for Microgravity (PCAM) held more than six times as many samples as are normally accommodated in the same amount of space.

A new experiment chamber called the Diffusion-Controlled Crystallization Apparatus for Microgravity (DCAM) also was tested. The experiment grew model proteins by a combination of the liquid-liquid diffusion and the dialysis methods of protein crystal growth. The principal investigator for this experiment was NASA’s Marshall Space Flight Center, Huntsville, AL.

Commercial Generic Bioprocessing Apparatus (CBGA): A tool which allowed a variety of sophisticated bioprocessing experiments to be performed in one piece of hardware.

Information gleaned from these experiments may help scientists understand the changes caused by exposure to microgravity in order to develop new drugs for the possible treatment of diseases such as cancer, osteoporosis and AIDS. The principal investigator for this experiment was the Center for Bioserve Space Technologies, University of Colorado, Boulder.

Ecological Test Systems: This group of investigations studied plant development and the relationships between bacteria and plants in microgravity. Such knowledge is crucial for extended stays in space where plants will be used as both a food source and a means of purifying air.

Biomaterials Products and Processes:
These experiments studied the growth of bacteria in microgravity, investigated new pharmaceutical products and delivery systems, and studied materials that might be used as replacements for skin, tendons, blood vessels and corneas. These investigations also provided important information on models for potential implants, such as synthetic skin for burn victims.

Astroculture Facility and Experiment:
The Astroculture facility was an apparatus used for growing plants in microgravity. The lighting subsystem has provided technology to develop a unique lighting system for photosynthesis research and for use in some medical applications. Other commercial products from Astroculture technology include dehumidification/humidification units, water-efficient irrigation systems and energy-efficient lighting systems for large scale commercial nurseries. The principal investigator for this experiment was the Wisconsin Center for Space Automation & Robotics, Madison, WI.

Orbital Acceleration Research Experiment: The Orbital Acceleration Research Experiment (OARE) was managed by Lewis Research Center as part of NASA's Microgravity Measurements and Analysis Project. Located outside the Spacelab, the OARE acceleration instrument measured microgravity levels caused by atmospheric drag of the shuttle, changes in orbiter velocity and vibrations of onboard machinery, as well as shuttle and crew operations.

High-Packed Digital Television Technical Demonstration: This was the first flight demonstration of a new digital television system to operate from the Spacelab. It provided researchers on the ground with up to six channels of video which could be transmitted simultaneously from orbit. Previously, only one video channel at a time could be sent down, or downlinked, limiting the accessibility of video data from experiments and other activities.

CREW BIOGRAPHIES

Commander: Kenneth D. Bowersox (Cdr. USN). Bowersox, 38, was born in Portsmouth, VA, but considers Bedford, IN, to be his hometown. He received a bachelor's degree in aerospace engineering from the United States Naval Academy, and a master's degree in mechanical engineering from Columbia University.

Bowersox received his commission in the Navy in 1978 and was designated a naval aviator in 1981. He was then assigned to Attack Squadron 22 aboard the USS Enterprise. Following graduation from the United States Air Force Test Pilot School at Edwards Air Force Base, California, in 1985, he moved to the Naval Weapon Center at China Lake, CA.

Bowersox has now logged more than 972 hours in space. His first flight, STS-50 in June/July 1992, was the first flight of the U.S. Microgravity Laboratory. Over a two-week period, crew members conducted a variety of experiments in materials processing and fluid dynamics in weightlessness.

At that time, STS-50 was the longest shuttle flight to date. Bowersox's second flight was as pilot of STS-61 in December 1993 and featured the servicing of the Hubble Space Telescope. During the 11-day mission, crew members conducted a record five space walks to restore the telescope to its full operating capacity.

Pilot: Kent Rominger (Cdr. USN). Rominger, 39, was born in Del Norte, CO, and received a bachelor's degree in civil engineering from Colorado State University and a master's degree in aeronautical engineering from the U.S. Naval Postgraduate School. He received his commission through the Aviation Reserve Officer Candidate Program and was designated a naval aviator in September 1980. Following training in the F-14 Tomcat, he was assigned to Fighter Squadron Two and attended the Navy fighter Weapons School

Rominger completed Naval Postgraduate School/Test Pilot School Cooperative Program, and was assigned as the F-14 Project Officer to the Carrier Suitability Branch of the Strike Aircraft Test Directorate at Patuxent River, MD. In 1990, he reported to Fighter Squadron 211 where he served as Operations Officer and completed a Desert Storm Deployment of the Arabian Gulf aboard the USS Nimitz. With the completion of STS-73 Rominger has now logged more than 382 hours in space.

Payload Commander: Kathryn Thornton, (Ph.D.). Thornton, 43, is a native of Montgomery, AL. She received a bachelor's degree in physics from Auburn University as well as a master's degree and doctorate in physics from the University of Virginia.

After receiving her doctorate, Thornton was awarded a NATO Postdoctoral Fellowship to continue her research at the Max Planck Institute for Nuclear Physics in Heidelberg, West Germany. She then returned to Charlottesville, VA, where she was employed as a physicist at the US Army Foreign Science and Technology Center.

Thornton has now logged more than 974 hours in space, including more than 21 hours of extravehicular activity.

Her first flight, in November 1989, was a five-day mission sponsored by the Department of Defense. Her second flight in May 1992 was aboard the maiden voyage of the Space Shuttle *Endeavour* on a mission to retrieve, repair and redeploy the International Telecommunications Satellite (INTELSAT), and to demonstrate and evaluate numerous EVA tasks to be used for the assembly of a space station. During that mission, Thornton and fellow crew member Tom Akers conducted a seven hour, 45 minute space walk.

On her third flight, Thornton was part of the team that conducted five space walks to service and repair the Hubble Space Telescope. During the December 1993 mission which lasted 11 days, Thornton performed two of the spacewalks, spending more than 13 EVA hours.

Mission Specialist: Catherine Coleman, Ph.D. (Capt. USAF). Coleman, 34, was born in Charleston, SC, and received a bachelor's degree in chemistry from the Massachusetts Institute of Technology, and a doctorate in polymer science and engineering from the University of Massachusetts.

Coleman was commissioned as a 2nd lieutenant in the Air Force and began graduate work at the University of Massachusetts. She did research on new polymer materials and acted as a surface analysis consultant for the Long Duration Exposure Facility. In addition to assigned duties, Coleman was a volunteer test subject for the centrifuge program at the Crew Systems Directorate of the Armstrong Aeromedical Laboratory. She set several endurance and tolerance records during her participation in physiological and new equipment studies. She has now logged more than 382 hours of space flight.

Mission Specialist: Michael Lopez-Alegria (Cdr. USN). Lopez-Alegria, 37, was born in Madrid, Spain, and considers both Madrid and Mission Viejo, CA, to be his hometowns. He earned a bachelor's degree in systems engineering from the U.S. Naval Academy, and a master's degree in aeronautical engineering from the U.S. Naval Postgraduate School. Lopez - Alegria was designated a naval aviator and served as a flight instructor in Pensacola, FL. He was assigned to a fleet electronic reconnaissance squadron in Rota, Spain, where he served as a pilot and mission commander aboard EP-3E aircraft, flying missions in the Mediterranean Sea, North Atlantic, Baltic Sea and Central America. He was also assigned to a two-year cooperative program between the Naval Postgraduate School in Monterey, CA, and the U.S. Naval Test Pilot School in Patuxent River, MD. His final tour before being assigned to NASA was at the Naval Air Test Center as an engineering test pilot and program manager. He has now logged more than 382 hours of

STS-73 crew on-orbit. Left to right front row: Kathryn Thonton, Michael Lopez-Alegria and Ken Bowersox. Middle row: Cady Coleman and Fred Leslie. Back row: Albert Sacco and Kent Rominger.

STS-73 Quick Look

Launch Date: Oct. 20, 1995
Launch Time: 8:53 a.m. CDT
Launch Site: KSC Pad 39B

Orbiter: *Columbia* (OV-102) 18th flight
Orbit/In.: 150 naut miles 39 degrees

Mission Duration: 15 days, 21 hours, 52 minutes

Landing Date: Nov. 5, 1995
Landing Time: 5:45 a.m. CDT
Landing Site: Kennedy Space Center

Crew: Ken Bowersox, CDR
Kent Rominger, PLT
Catherine Coleman, MS1
Michael Lopez-Alegria, MS2
Kathryn Thornton, MS3
Fred Leslie, PS1
Albert Sacco, PS2

Cargo Bay Payloads: USML-2
OARE

space flight.

Payload Specialist: Fred Leslie, (Ph.D.). Leslie, 43, was born in Ancon, Panama. He received a bachelor's degree in engineering science from the University of Texas, and a master's and doctorate degrees in meteorology with a minor in fluid mechanics from the University of Oklahoma.

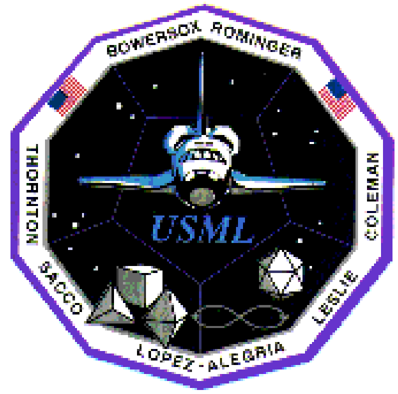
Leslie served as a post doctoral research associate at Purdue University studying fluid vortex dynamics, and worked for the Universities Space Research Association as a visiting scientist at the Marshall Space Flight Center.

He as also served as a co-investigator for the Geophysical Fluid Flow Cell experiment that flew on the Spacelab 3 mission and is part of the USML-2 payload. He also was a principal investigator for the Fluid Interface and Bubble Experiment examining the behavior of a rotating free surface aboard NASA's KC-135 aircraft. He is the author of 27 journal papers, 45 conference papers, and nine NASA reports involving atmospheric and fluid dynamic phenomena.

He was chief of the Fluid Dynamics Branch directing and conducting research in both laboratory and theoretical investigations. He also was the mission scientist for the Japanese Spacelab mission, STS-47.

Payload Specialist: Albert Sacco, Jr. (Ph.D.). Sacco, 46, is a native of Boston, MA, and received a bachelor's degree with honors from Northeastern University and a doctorate from the Massachusetts Institute of Technology, both in chemical engineering. Sacco has been on the faculty at Worcester Polytechnic Institute in the Department of Chemical Engineering, splitting his time between research and teaching. He has consulted for numerous companies in the field of catalysis, solid/gas contacting, and equipment design for space applications.

Sacco has more than 70 publications in the areas of carbon filament initiation and growth, catalyst deactivation, and zeolite synthesis. He is the principal investigator for the Zeolite Crystal Growth Experiment.



The crew patch depicts Shuttle *Columbia* in the vastness of space. In the foreground are the classic regular polyhedrons that were investigated by Plato and later Euclid. The Pytha-goreans were fascinated by the sym-metrical three-dimensional objects whose sides are the same regular polygon. The tetrahedron, the cube, the octahedron, and the icosa-hedron were associated with the “Natural Elements” of that time: fire (combustion science), earth (crystal-lography), air and water (fluid physics). An additional icon shown as the infinity symbol was added to further convey the discipline of fluid mechanics. The shape of the emblem represents a fifth poly-hedron, a dodecahedron, which the Pythagoreans thought corresponded to a fifth element that represented the cosmos.